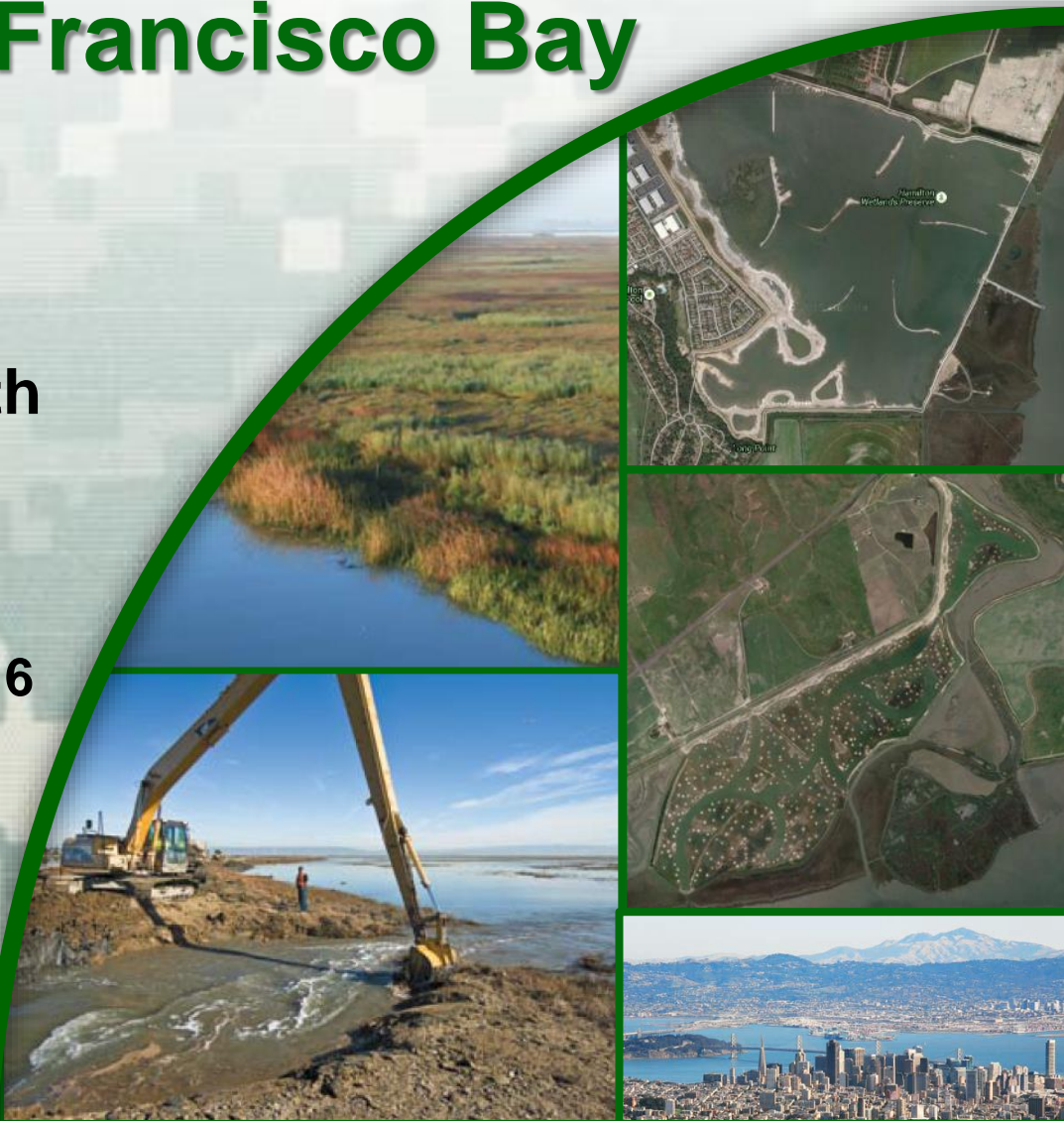# Evaluation of Berm Shape for Wave Energy Reduction in Restored Tidal Wetlands in San Francisco Bay

**Elizabeth Murray,
Jane McKee Smith,
Thad Pratt, & Jarrell Smith**

**Engineering Research and
Development Center
For California DredgeFest 2016**

US Army Corps of Engineers
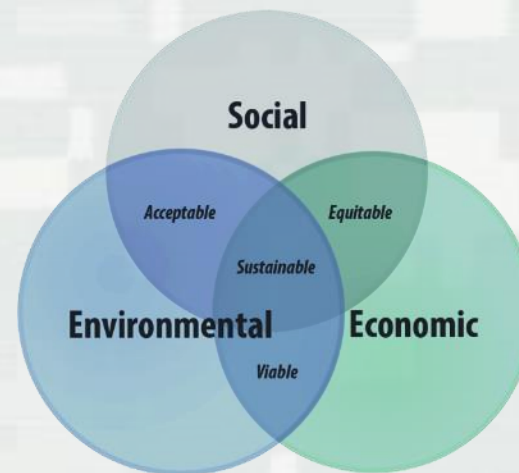**BUILDING STRONG**®

The U.S. Army Engineer Research and Development Center (ERDC)

- Coastal and Hydraulics Laboratory (CHL)
- Environmental Laboratory (EL)
- Geotechnical and Structures Laboratory (GSL)
- Information Technology Laboratory (ITL)
- Geospatial Research Laboratory (GRL)
- Construction Engineering Research Laboratory (CERL)
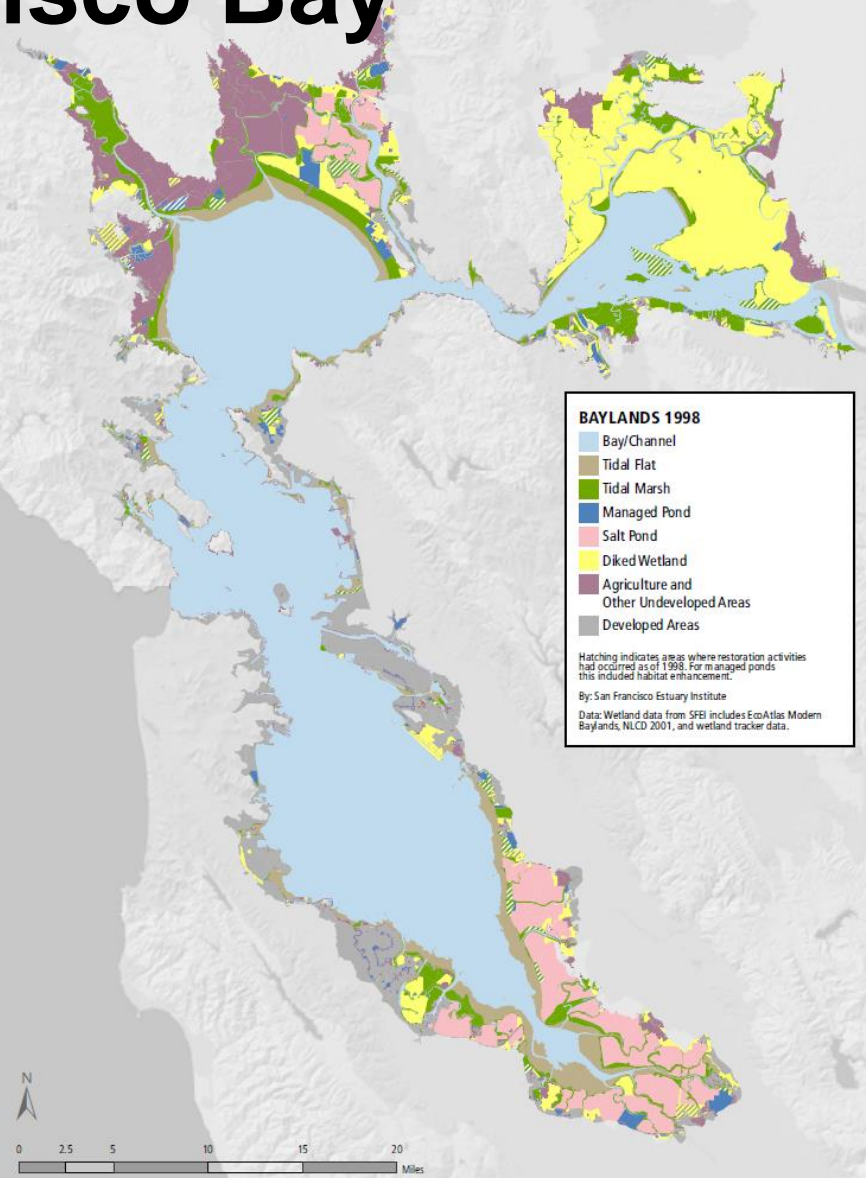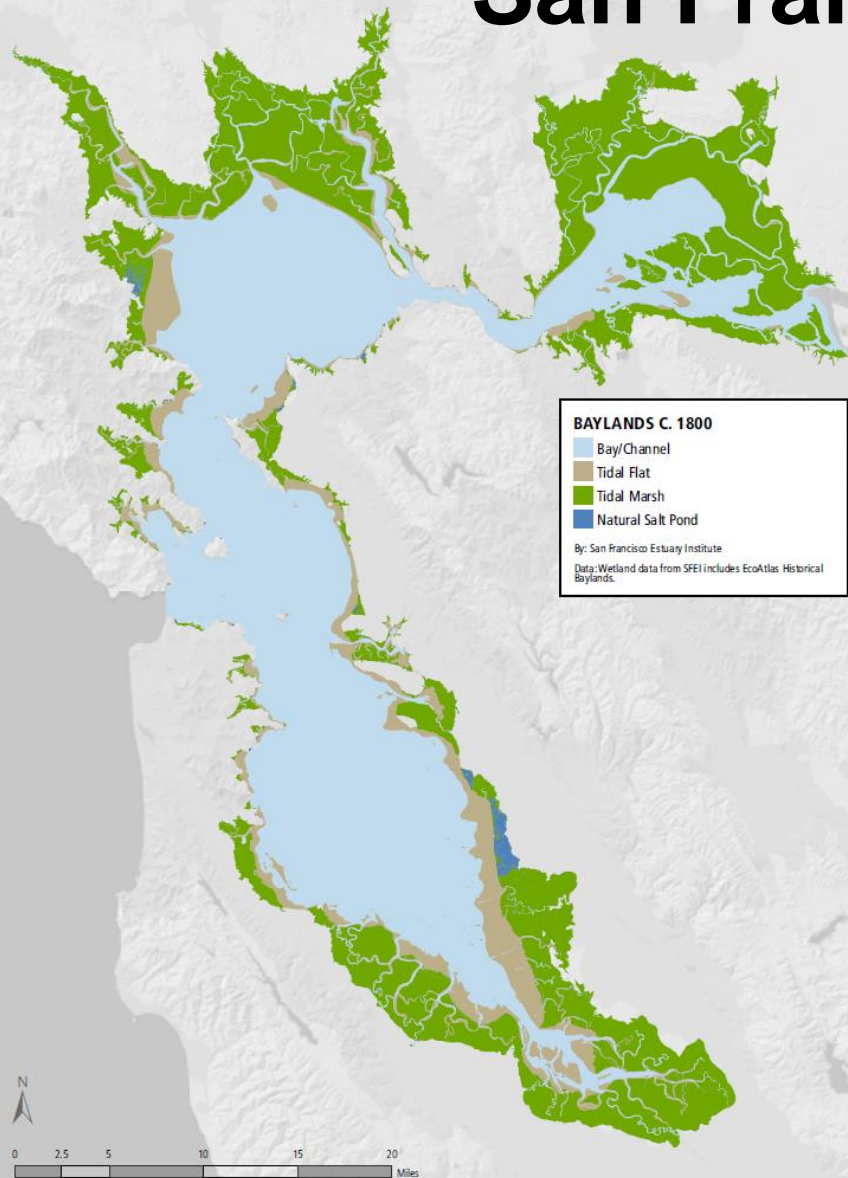- Cold Regions Research and Engineering Laboratory (CRREL)

Engineering With Nature…

…the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes.

Social
Acceptable   Equitable
Sustainable
Environmental   Economic
Viable

- Using natural process to maximum benefit

EWN

San Francisco Bay

BAYLANDS C. 1800
- Bay/Channel
- Tidal Flat
- Tidal Marsh
- Natural Salt Pond

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes EcoAtlas Historical Baylands.

BAYLANDS 1998
- Bay/Channel
- Tidal Flat
- Tidal Marsh
- Managed Pond
- Salt Pond
- Diked Wetland
- Agriculture and Other Undeveloped Areas
- Developed Areas

Hatching indicates areas where restoration activities had occurred as of 1998. For managed ponds this included habitat enhancement.

By: San Francisco Estuary Institute

Data: Wetland data from SFEI includes EcoAtlas Modern Baylands, NLCD 2001, and wetland tracker data.
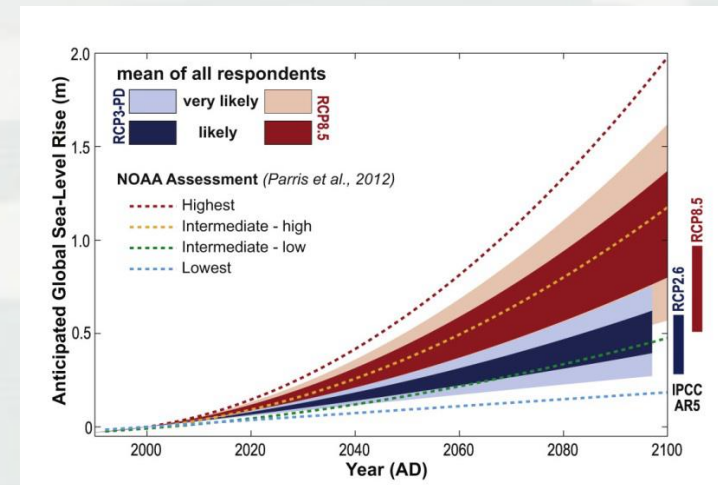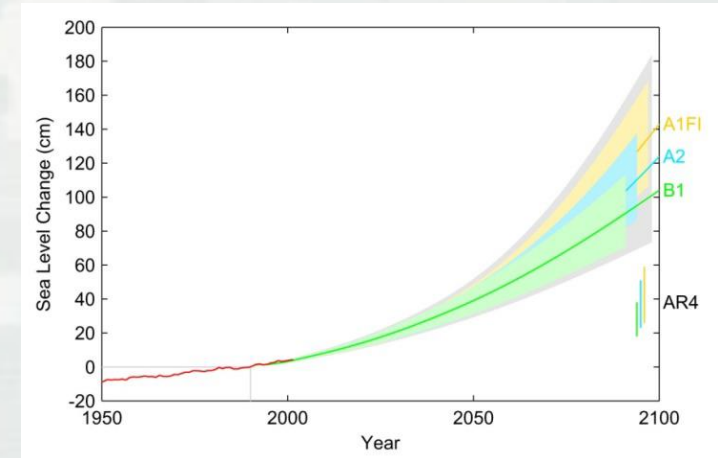
San Francisco Bay

San Francisco, CA

- 90% of tidal wetlands filled

- Reduced habitat

- Endangered plant & animal species

- Removed buffer for rising sea level

Global Sea Level Projections (by 2100)

- **0.5 to 1.9 m** Rahmstorf (*Science*, 2007)/ Vermeer and Rahmstorf (*PNAS*, 2009)
  - ▶ relates sea level rise to mean surface temperature

- **0.8 to 2 m** Pfeffer et al. (*Science*, 2008)
  - ▶ constrained by observations of ice sheet dynamics

- **5 m** Hansen (*Environ. Res. Lett.*, 2007)
  - ▶ non-linearity, amplifying polar feedbacks- 'albedo flip'
  - ▶ New paper in *Atmospheric Chemistry and Physics*

- **0.26 to 0.82 m** Intergovernmental Panel on Climate Change (*IPCC*, 2014)
  - ▶ ice sheet contributions from Greenland (7 m stored) and Antarctica (60 m + stored) conservatively included (excluded in AR4: IPCC, 2007)

- **0.4 to 1.2 m** Horton et al. (*QSR*, 2014)
  - ▶ expert assessment of median range

Compiled by USGS

Projections for San Francisco Area

- **SLR for San Francisco (NRC, 2012)**
  - ► 28 cm of sea level rise by 2050 (range 12-61 cm)
  - ► 92 cm of sea level rise by 2100 (range 42-166 cm)
- **Storms for California**
  - ► No significant changes in wave height
  - ► Extreme events approach from ~10-15 degrees further south
- **El Niño for 21st Century**
  - ► More frequent extreme events
  - ► Doubling of winter erosion
  - ► Wave energy increase by 30%
- **Net effect**
  - ► Today's 100-year coastal water level event is projected to occur every 1-5 years by 2050 for much of California
  - ► Greatest impacts on low-lying coastal areas (e.g., Stinson Beach, San Francisco Bay)

EWN

2) Choose an Amount of Sea Lev∧

| 0 | 25 | 50 | 75 | 100 | 125 |
| 150 | 175 | 200 | 500 | [Use feet] | |

What Sea Level Rise scenario
should I use?

3) Choose an Event

Choose
Storm Scenario Frequency

| None | Annual | 20 year | 100 year |

Or Choose
King Tide Scenario

| King Tide |

What are Storm Scenarios?
What is a King Tide scenario?

4) Choose other layers
to view with
topic data.

☐ Digital Elev Model (DEM)
☐ Levees
☐ Placenames
☐ Land Use
☐ Protected Areas
☐ Rivers & Streams
☐ Cliff and Shoreline Retreat
☐ Shorebirds
☐ Coastal Armoring
☐ Roads and Transportation
☐ Trails
☐ Buildings
☐ Utilities & Services
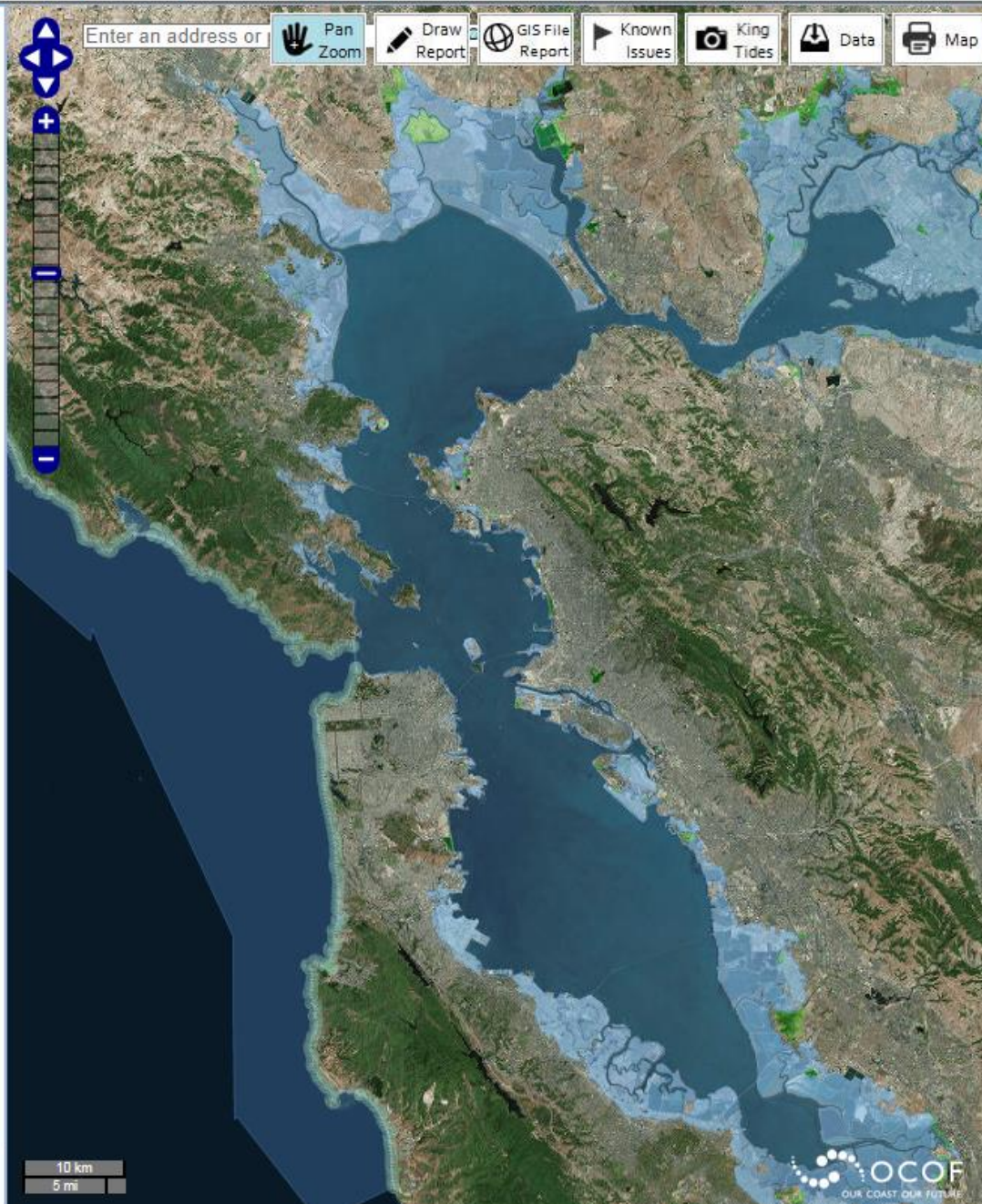
What do Other Layers represent?

Opacity

◀ | 0.5 | ▶

Metadata

Detail View «

Enter an address or | Pan Zoom | Draw Report | GIS File Report | Known Issues | King Tides | Data | Map

Max Wave Runup during Flood
100cm SLR + Wave 100
○

Flood-prone Low-lying Areas
100cm SLR + Wave 100
🟩

Flood Hazard 100cm SLR + Wave
100
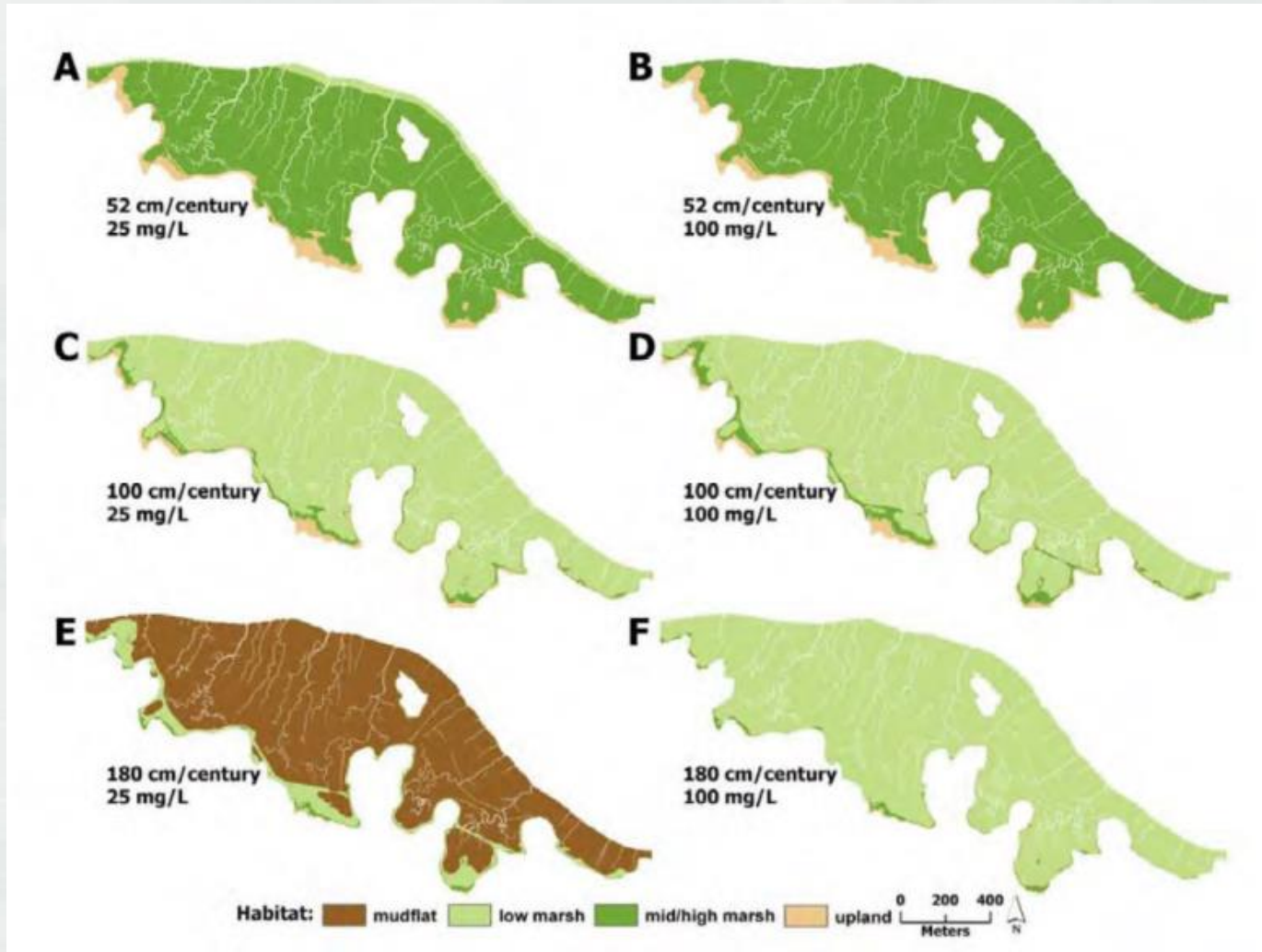🟦

Flood Depth 100cm SLR + Wave
100
✗ No Data

0 cm

250 cm

500 cm

750 cm

10 km
5 mi

OCOF
OUR COAST OUR FUTURE

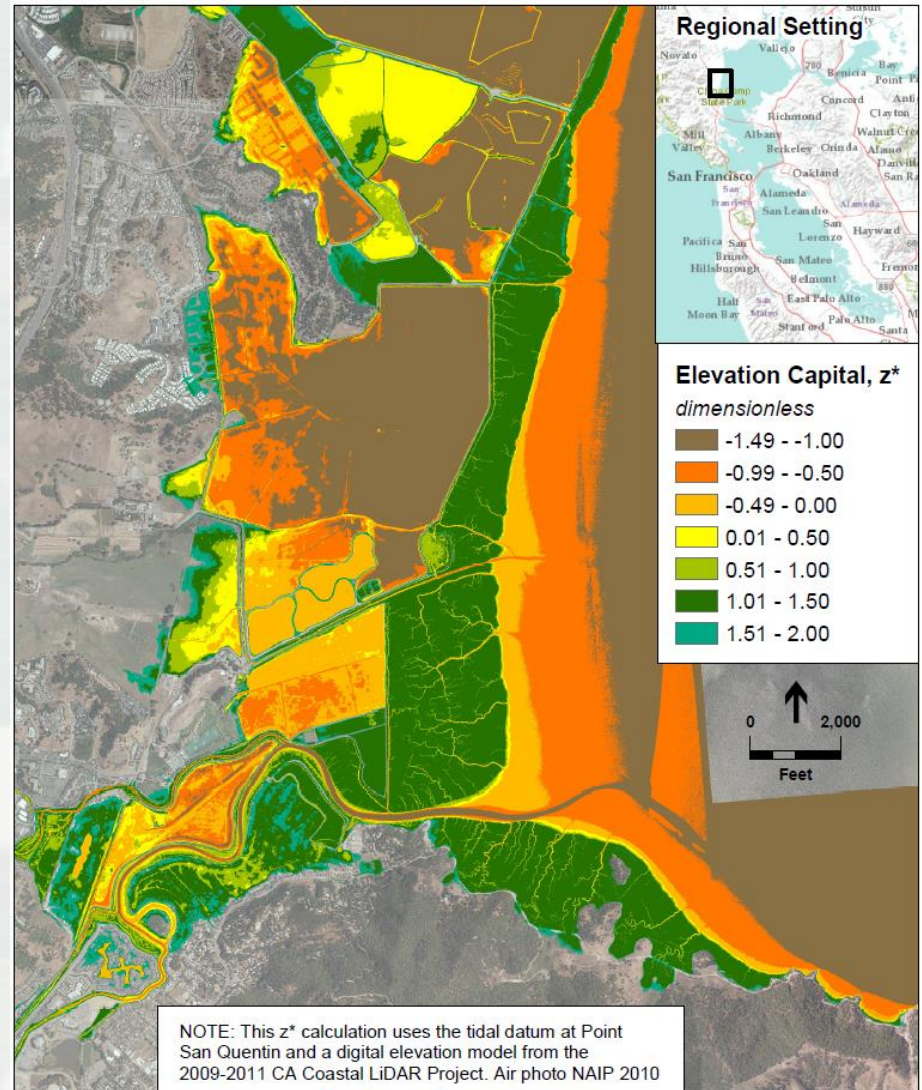# Modeling Suggests that Existing Marshes Won't Keep Up with SLR Without Sediment Influx

From Schile et al. (2014)

Diked Baylands Have Subsided 1-2m

- **Compare absolute elevation of a marsh with the local water levels and tide range.**

- **Dark green are marsh elevations.**

- **Yellow, orange and brown are below marsh elevation.**

In order to restore these diked baylands, sediment needs to be brought in or encouraged to accrete.

Regional Setting

Elevation Capital, z*
dimensionless

	-1.49 - -1.00
	-0.99 - -0.50
	-0.49 - 0.00
	0.01 - 0.50
	0.51 - 1.00
	1.01 - 1.50
	1.51 - 2.00

0   2,000
Feet

NOTE: This z* calculation uses the tidal datum at Point San Quentin and a digital elevation model from the 2009-2011 CA Coastal LiDAR Project. Air photo NAIP 2010
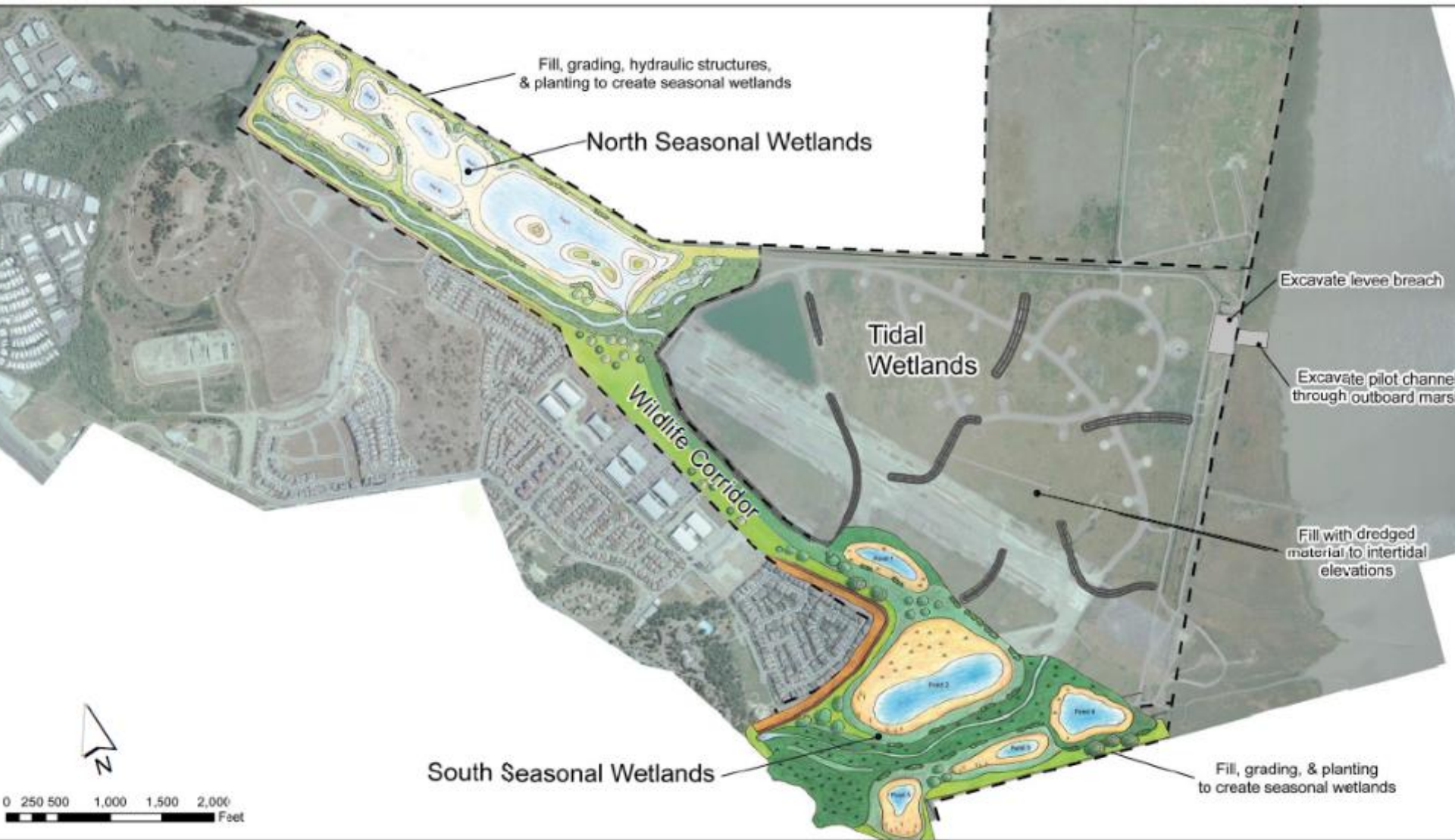
Hamilton Bay Restoration

- Site diked ~100 yr ago, Hamilton Army Airfield

- Significant subsidence

- 650-acre wetland restoration, 20 yrs

- Beneficial use of 24.4 mill yd^3 of dredged material

- Wetland design w/ berms

- U.S. Army Corps of Engineers and the California Coastal Conservancy
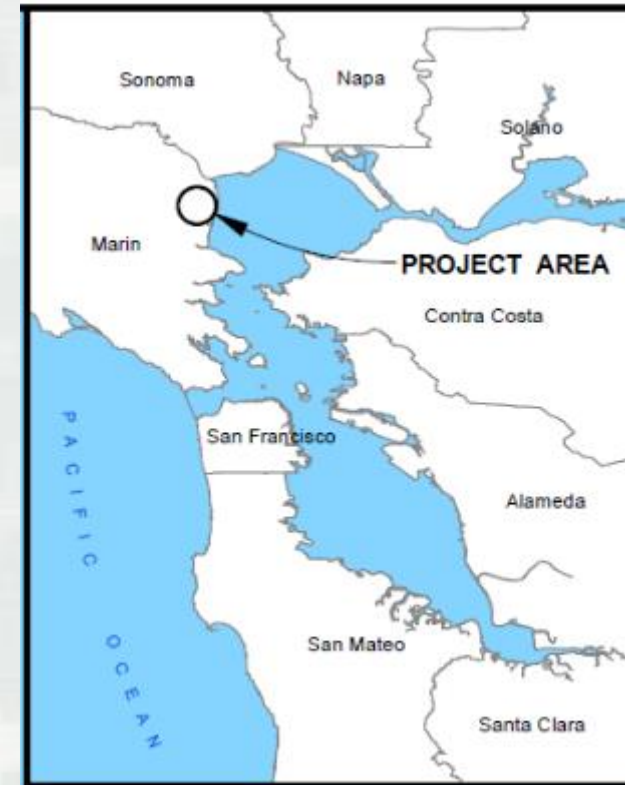
Hamilton Bay Restoration

Sears Point Restoration

- Similar environment to Hamilton
- 955 acre tidal wetland restoration
- Wetland design w/ mounds
- Sonoma Land Trust and Ducks Unlimited

Sears Point Restoration

Imagery Date: 4/1/2015   38°07'54.00" N 122°27'12.78" W

Compare Berms and Mounds for Wave Reduction

- Berm = linear feature

- Mound = circular feature

- Sears Point behind schedule for breaching

- So…

  ► Simulated Hamilton in a wave model with berms

  ► Removed berms and ran same wave conditions

  ► Add mounds of ~ same volume, sized similar to mounds at Sears Point.

Hamilton Field Data Collection

- Waves (wave staffs)
- Water Levels
- Currents
- Salinity
- Conductivity
- Temperature
- Wind Speed and Direction
- Sedimentation

STWAVE

- Phase-averaged, spectra wave model (growth, transformation, and dissipation)

- Wave-vegetation interaction based on Mendez and Losada (2004)

- Wave-current interaction neglected in simulations

Bathymetry of Hamilton Model under Different Scenario Runs
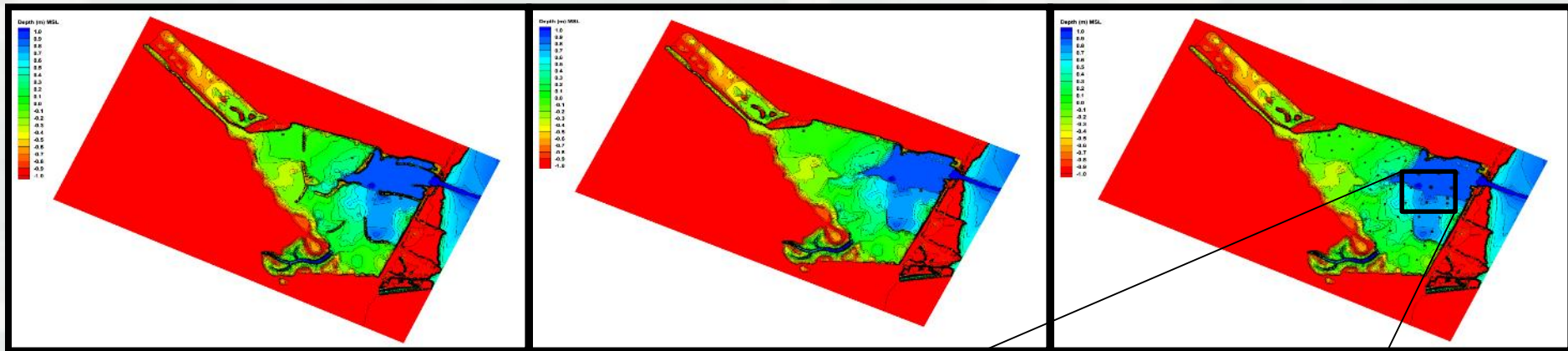
Linear Berms (As-Built)   **No Berms (Control)**   **Mounds (ala Sears Pt.)**

Model mounds based on LiDAR of Sears Point Mounds

Validation

- Two Storms
  - ► Feb 2015
    - 9 m/s NW
  - ► April 2015
    - 10 m/s SW

| Date	H_{mo} mean error	H_{mo} rms error	T_m mean error	T_m RMS error
Feb 2015	0.013 m	0.028 m	0.21 sec	0.23 sec
Apr 2015	-0.0024 m	0.053 m	0.19 sec	0.25 sec

Idealized Simulations

- Winds of 15 and 20 m/s (14-yr wind record at Richmond, CA)

- Water levels of + 0.5 and +1.0 MSL

- 8 wind directions (N, NE, E, SE, S, SW, W, NW)

- With and without vegetation
  - ► Pickleweed
  - ► Within depth range of +0.4-0.95 m MSL
  - ► C_D = 0.1, stem height=0.6 m, density = 300/m² diameter = 0.01 m (Northwest Hydraulic Consultants 2011)

EWN

Wave Height of Hamilton Model under Different Scenario Runs
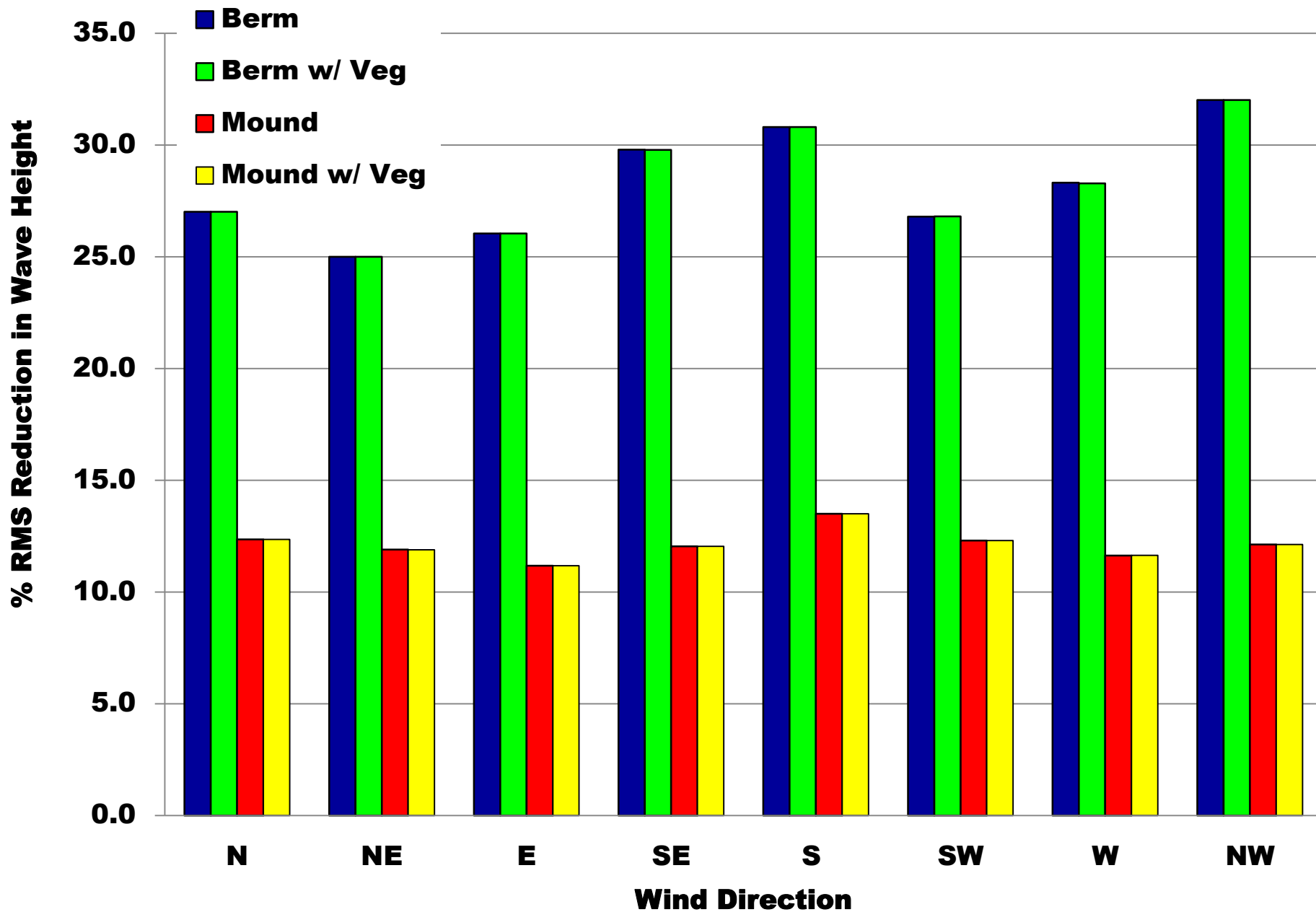## Wave heights for 20 m/s wind from W, 0.5 m (MSL) tide, no vegetation
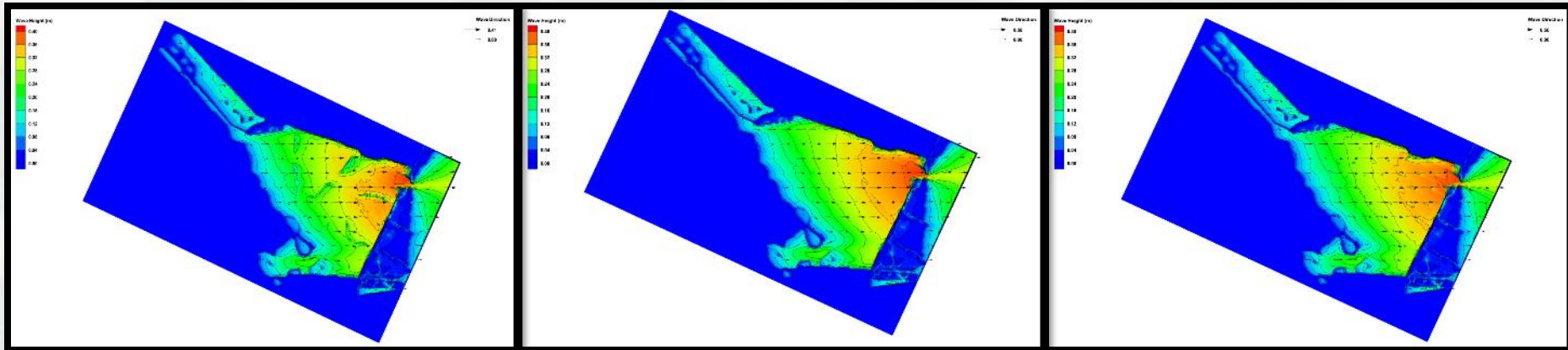
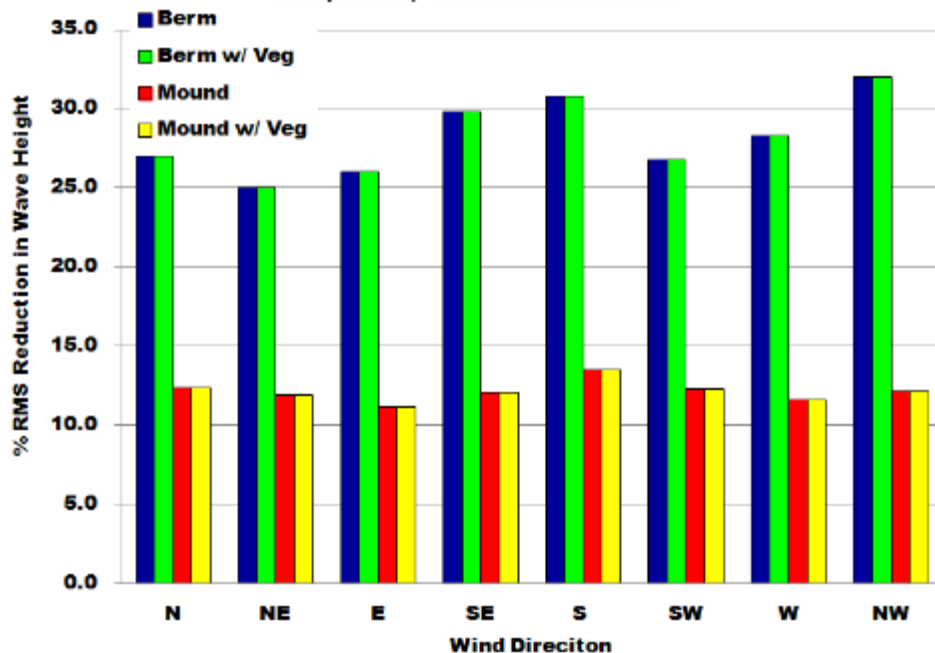**Linear Berms (As-Built)**   **No Berms (Control)**   **Mounds (ala Sears Pt.)**

Other scenarios: different wind directions, wave at entrance, vegetation based on parameters for Pickleweed and *Spartina foliosa,* determined for wave attenuation research at Corte Madera, a nearby salt marsh in San Francisco Bay.
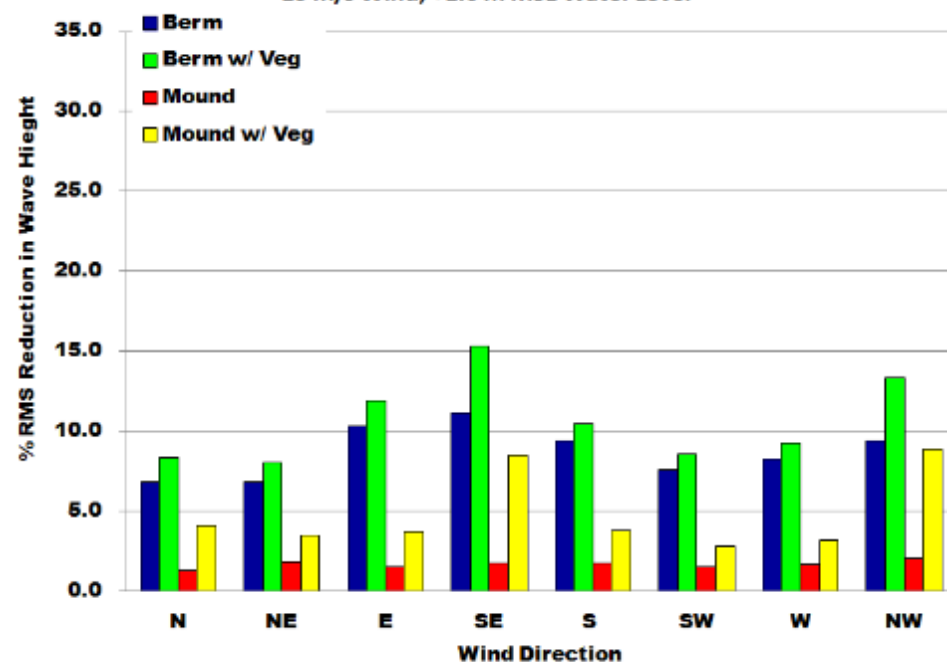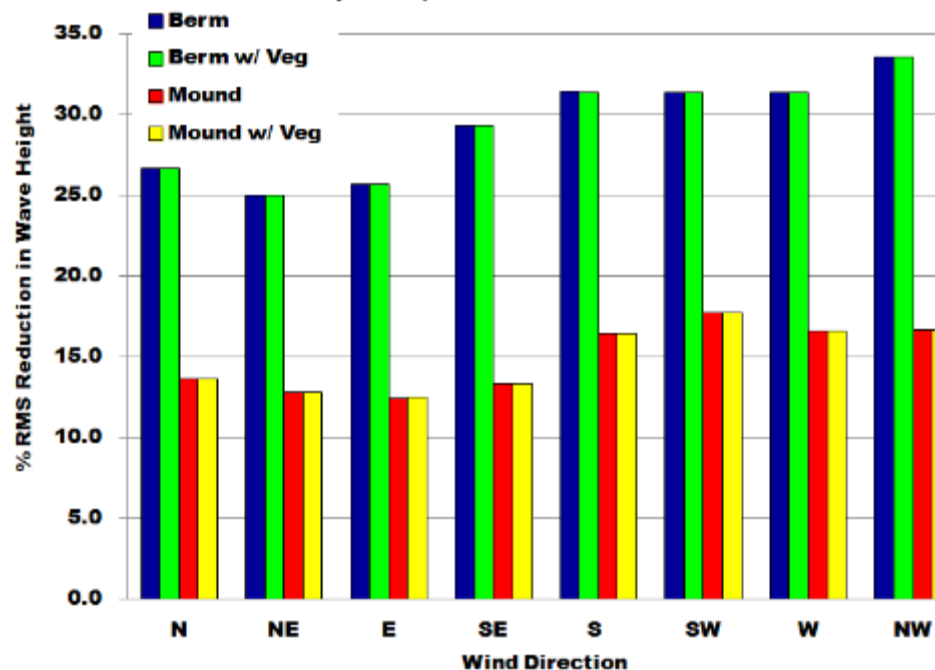
15 m/s Wind, +0.5 m MSL Water Level
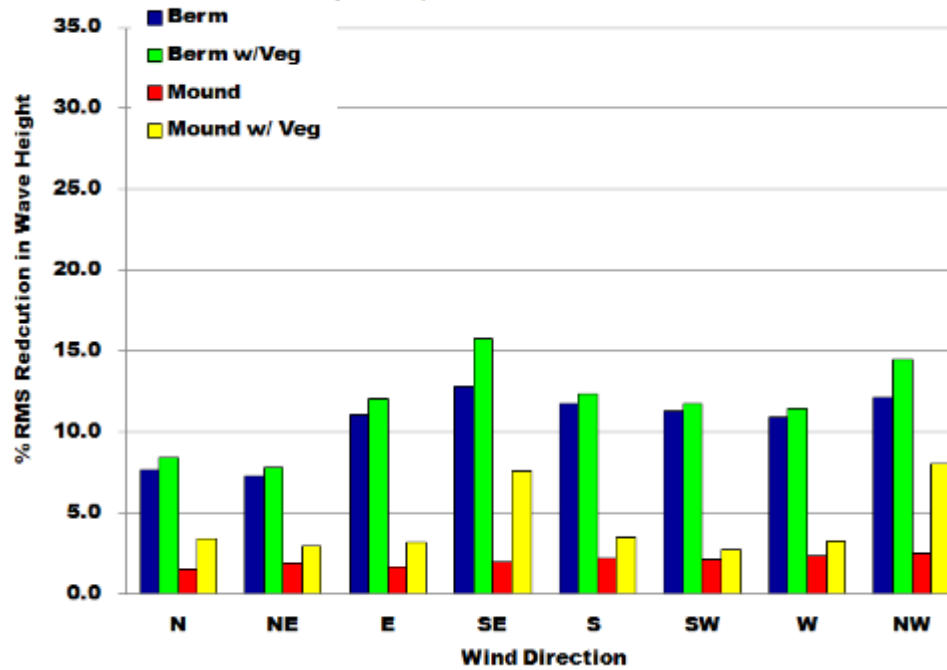
15 m/s Wind, +0.5 m MSL Water Level — % RMS Reduction in Wave Height vs. Wind Direction (N, NE, E, SE, S, SW, W, NW) for Berm, Berm w/ Veg, Mound, Mound w/ Veg.

15 m/s Wind, +1.0 m MSL Water Level — % RMS Redcution in Wave Height vs. Wind Direction (N, NE, E, SE, S, SW, W, NW) for Berm, Berm w/ Veg, Mound, Mound w/ Veg.

20 m/s Wind, +0.5 m MSL Water Level — % RMS Reduction in Wave Height vs. Wind Direction (N, NE, E, SE, S, SW, W, NW) for Berm, Berm w/ Veg, Mound, Mound w/ Veg.

20 m/s Wind, +1.0 m MSL Water Level — % RMS Redcution in Wave Height vs. Wind Direction (N, NE, E, SE, S, SW, W, NW) for Berm, Berm w/Veg, Mound, Mound w/ Veg.

Summary

- As modeled at Hamilton, linear berms produced a greater reduction in wave height than circular mounds:
  - ▶ 25-32% at 0.5m MSL Berms
  - ▶ 11-14% at 0.5m MSL Mounds
- Wave height attenuation by berms AND mounds decreases significantly once they are submerged (75% reduction 1m v. 0.5m MSL)
- Vegetation increases wave height reductions (when vegetation is submerged), vegetation impact greater for circular mounds

Next Steps

- Sears Point is being monitored now.

- Building wave model and running similar simulations this summer.

- Sears Point has different configuration, placement in bay, and depth, which may affect results.

- Will also compare channel evolution to see if we can detect difference in mounds versus berms.